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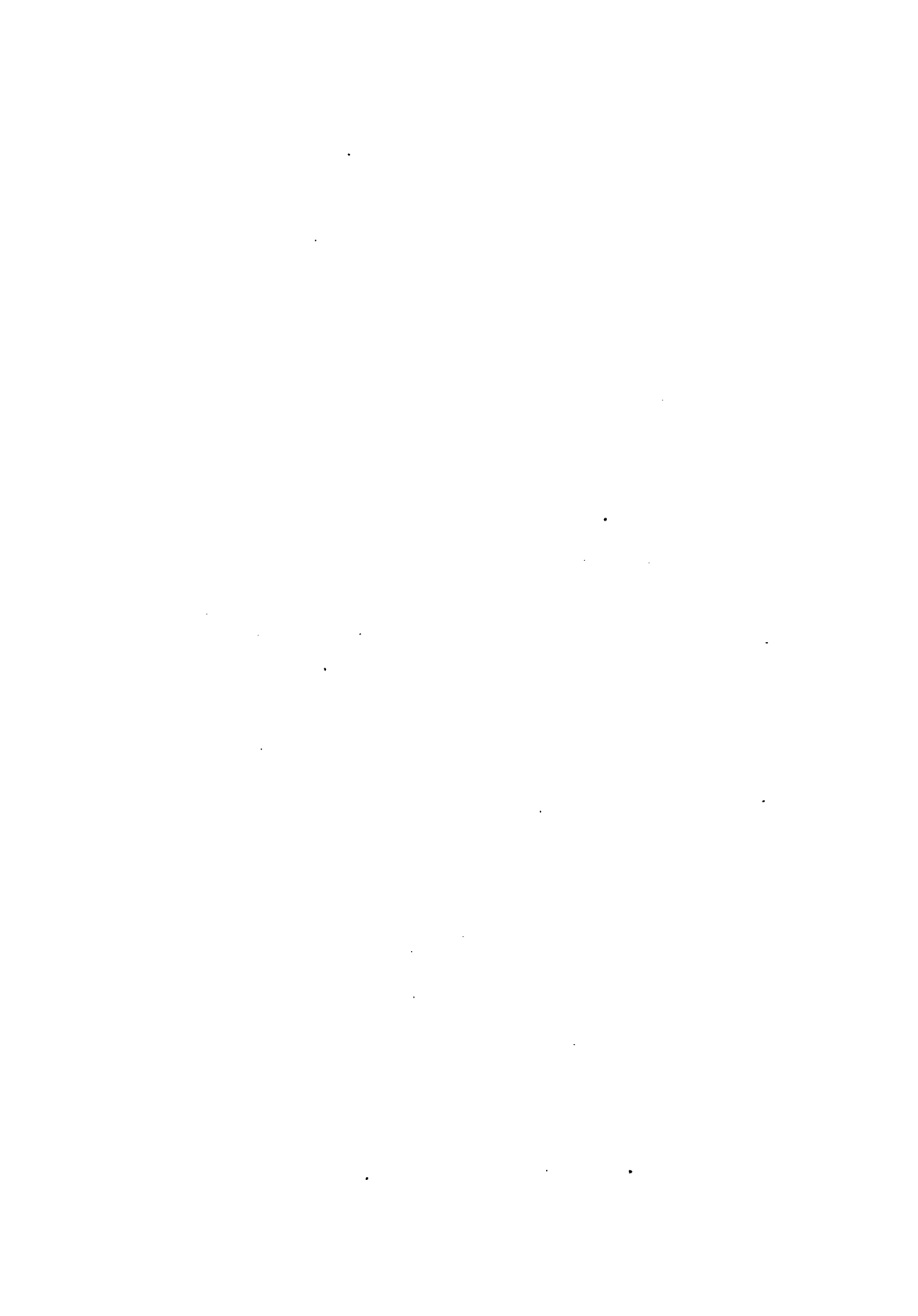
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THE

COSMOSPHERE:

AN

INSTRUMENT

SUBSTITUTING

AN ORRERY, A PLANETARIUM, A TELLURIUM, A LUNARIUM,
AN ARMILLARY SPHERE, A CELESTIAL AND
A TERRESTRIAL GLOBE,

For Self-instruction and for Schools.

WITH AN

APPENDIX,

ON

THE USE OF A COSMOSPHERE, OF AN ORBOGRAPH, OF A
LOXODROMOGRAPH, AND OF A SPHEROMETER,

INSTRUMENTS FOR CALCULATING

THE LATITUDE AND LONGITUDE AT SEA.

BY

DR. W. MULLER,

MAJOR OF THE ROYAL HANOVERIAN ENGINEERS.

LONDON:

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1829.

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THE COSMOSPHERE.

DESCRIPTION AND USE OF THE COSMOSPHERE, AN
INSTRUMENT SUBSTITUTING A PLANETARIUM, AN
ORRERY, A TELLURIUM, AN ARMILLARY SPHERE,
A CELESTIAL AND A TERRESTRIAL GLOBE.

I.—DESCRIPTION OF THE COSMOSPHERE.

1.—The Cosmosphere is an apparatus which will represent and explain the universe, or, I. the solar system, viz. the motion of the sun, the planets, (bodies which move round the sun,) and the satellites, (bodies which revolve round the planets;) and II. other celestial bodies, as fixed stars, (called thus on account of their never, or almost imperceptibly changing their respective stations,) which are seen on the vault of heaven.

2.—A Cosmosphere contains the following parts:—

I. A representation of the starred sky, with the celestial bodies on it, by a transparent globe, which may revolve round its centre in any direction required. The stars on the surface of the transparent globe have been represented in different colours, according to their magnitudes, and in their relative positions, as they appear to the eye of a person from our earth. All stars, except those near two opposite points in the sky, appear to revolve round a line between the two said points of the sky. These two points are called the poles, and the line between them is the axis of the world. The transparent globe revolves round a line or an axis, invisible, like that of the world. Its ends repre-

sent the poles of the world. On the transparent globe are likewise represented, A, the equator, (a circle at an equal distance from the poles;) B, the ecliptic, (a circle inclined 23.5 degrees on the equator, and representing a circle, or rather a curve, in which the centre of the earth moves round the sun;) C, the colures, (two large circles placed perpendicularly on the equator, one passing through the intersections of the equator and the ecliptic, and the other through the points where the ecliptic has the greatest distance from the equator;) D, the two polar circles, (two circles 23.5 degrees distant from each of the poles, and parallel to the equator;) E, the two tropical circles, or two circles parallel to the equator, and about 23.5 degrees from it; and F, the circles of precession of the poles, or two circles diametrically opposite, through the poles of the equator, and round the poles of the ecliptic, or round two points diametrically opposite, and at an equal distance from the ecliptic, on the surface of the ball.

II. A planetarium, consisting of an ivory ball on a wire, representing the sun and other balls fixed to arms, which may move round the wire within the transparent globe representing the sky.* These balls represent the planets, and round some of these balls again smaller ones, (which may move round the planets as the planets round the sun,) are to be fixed in a similar manner by wires. These smaller balls represent the satellites. The planetarium may be placed with the one end of the wire on the other of which the ball representing the sun is fixed in the pole of the ecliptic, consequently in its proper position within the transparent globe representing the sky.

* Either a planetarium, or a lunarium, or a terrestrial globe may be put in a transparent globe, by opening the two transparent hemispheres carefully, and placing either of them in their proper place in the transparent globe, and shutting and fixing it again properly in its position.

III. A small ball on a wire to represent the sun. Through its centre is laid a transparent or opaque plane, to show the plane of the orbit or curve in which the earth moves round the sun. In this orbit four small balls, representing the earth, and through their centre other transparent planes, to show the orbit of the moon round the earth, are fixed, and on them are placed smaller balls representing the moon. This part is likewise to be placed, that the ball, called the sun, falls in the centre of the transparent globe, and the wire with the other end in the pole of the ecliptic. This part of the apparatus serves to explain the motions of the earth and moon.

IV. A terrestrial globe, of the most improved construction, to be placed in the transparent ball, so that the centre of both falls in one point, and the axis of the terrestrial globe fits in the poles of the equator of the transparent hemispheres. This axis of the terrestrial globe has a loose prolongation to turn it from the outside of the transparent globe. Round the terrestrial globe lies a ring with proper divisions. It is fixed to another ring, and a semi-ring standing perpendicularly on both, and equally distant from the intersection of both. By a screw-nut and catch on each side of the axis of the terrestrial globe, this is fixed to the undivided ring, to fix this in any required position. Where the semi-ring meets the ring without divisions, is fixed a small piece of brass, with a small tube, and in this tube is a fine pin. It points with one end to a point on the terrestrial globe, representing the place of a person on our earth; and with the other end to the point above, representing the zenith in the sky. This pin is equally distant from the divided circle called the horizon, and may be moved to any part of the terrestrial globe, and be kept there by screwing the two nuts round the axis towards the globe. The globe, when turned by the loose prolongation of its axis, will move equally with a hand on the loose

prolongation of the axis. This hand shows the hour on a dial plate.

V. A strong ring round the transparent ball, called the general meridian, and which has a division on one side in four quadrants. The centre of this division is to lay in the same point with the centre of the transparent ball, so that this may be turned within the ring in any direction. Above the meridian is a dial-plate, divided to twenty-four hours. The hand mentioned in IV, shows the hour on it.

VI. The general meridian may be suspended or be supported by two lips, and a screw of pressure, fixed to a stand of metal or wood. Any part of the general meridian may thus be kept above or below.

VII. A tube to slide on the general meridian. It has a point in its centre, to mark any point of the division on the general meridian. Two divided quadrants are fixed to it, so as to turn round the tube. This tube is called the tube of the axis of altitudes, and the quadrants the quadrants of altitude. On each of the quadrants slides a small bar, with a notch at the top, and a point near the quadrants: they are called the rays of altitude. To the point 0° , or the beginning of the quadrants, is to be fixed a ring with several divisions on it. It is called the general or first horizon.

VIII. Such of the Cosmospheres as have brass rings to represent the equator, the ecliptic, the colures, and the circles of precession, ought to have a micrometer screw, applicable to the fine motion of the tube on the general meridian, and another micrometer screw, to be applied to the general meridian and the equator for a similar purpose.

IX. A ring, on one side divided, with another half ring standing perpendicularly on the divided side of the ring. Through the middle of the semi-ring, and at 90 degrees from the divided surface of the ring, is a hole to mark the pole of the ring. At twenty-three degrees and a half from

this pole is another small hole, to represent the pole of the ecliptic, if the first is the pole of the equator. Under proper distances from the said holes are others, which mark the inclinations of the orbits of the moon and the planets on the ecliptic, according to the marks near them. This instrument is named an Orbograph.

The signs of the sun and planets are:

☉ Sun.	♆ Juno.
☿ Mercury.	♁ Pallas.
♀ Venus.	♁ Vesta.
♁ Earth.	♃ Jupiter.
♂ Mars.	♄ Saturn.
♁ Ceres.	♁ Georgium Sidus.
♁ The Moon.	

II.—ON THE CONSTRUCTION OF THE COSMOSPHERICAL APPARATUS FOR DIFFERENT PURPOSES.

Sec. 3.—The construction of the Cosmo-spherical Apparatus differs, as mentioned in the note of No. 2, II, according to the purpose to which it is to be applied, whether, I, it is required to explain the system of the universe, and the orbits in which the planets and satellites, and the comets appear to move in the sky; or, II, the motion of the earth and the moon, with the orbits in which the sun appears to move, and that in which the moon revolves round the earth; or, III, the diurnal motion of the earth, in regard to the sun and the orbit of the planets, the moon, &c.

Sec. 4.—Apparatus I, for shewing the motion of the planets round the sun, and their orbits in the sky, is constructed in the following manner:

A.—Suspend or support the general meridian, the transparent ball being in it.

B.—If the general meridian is suspended, take the transparent ball carefully out of it, after unscrewing the screws,

which fix it in the poles to the general meridian ; open the hemispheres, fix the planetarium as mentioned in sec. 2, II, and fix the transparent globe together, and in the general meridian, as before. But if the globe is supported, fix the lower transparent hemisphere to the general meridian, by putting some doubled papers, &c. between both ; unscrew the screw which fixes the upper hemisphere to the meridian, open the upper half of the meridian, take the upper hemisphere from the lower, and put the planetarium in, as described in sec. 2, II ; put the upper hemisphere on the lower, shut the general meridian, fix the screw to keep it together, and screw the nut in the pole of the upper hemisphere, to keep it to the meridian. The orbits of the planets may be traced on the surface of the transparent globe, by applying the orbograph mentioned in sec. 2, IX, after fixing glass paper on the proper part of the surface of the transparent hemisphere, and keeping the lower hemisphere steady in its proper position within the general meridian, while the screw at the top of the other is removed.

Sec. 5.—Apparatus II, for showing the motion of the earth round the sun, and that of the moon round the earth, is to be constructed by placing the lunarium mentioned in sec. 2, III, in the transparent globe, in the place of the planetarium, as mentioned in sec. 4. For tracing the moon's orbit, the orbograph mentioned in sec. 2, IX, may be applied as mentioned in sec. 4.

Sec. 6.—Apparatus III, to show the motions of the earth comparatively to the sky, is constructed by placing, instead of the planetarium or tellurium, the terrestrial globe, with its axis in the poles of the equator of the transparent globe, and carefully shutting and fixing both hemispheres in the general meridian. The orbits of the moon and the planets may likewise be traced, if required, as mentioned in sec. 4.

III.—GENERAL EXPLANATIONS OF VARIOUS PARTS OF THE COSMOSPHERICAL APPARATUS.

Sec. 7.—I. A person of middling size generally occupies on the surface of the earth one square foot. Comparing this to a room of eighteen feet in breadth, and twenty feet in width, this space would contain about 360 persons, all standing close together; and comparatively would any room to a good house, or the houses of a street, occupy a very small part on the surface of the earth. And again, a large house, or the houses of a street, will only be a small part of a large town. The space of the town comparatively to that of a province, and still more to that of a kingdom, will however be very small; and still smaller, and exceedingly small, will comparatively be the place occupied by a house. A kingdom occupies again only a small part of Europe, and Europe again of the surface of the earth; a large town will therefore appear only a small speck, and consequently the space or square contents occupied by a room, or even by a house, will be extremely small, and scarcely conceivable, comparatively to the square contents of the surface of our globe. Considering now the surface of a ball having twenty-four feet in diameter, it results that a town larger than London, or eleven miles long and eleven wide, or containing 121 square miles, will only occupy about a quarter of a square inch on the said globe, having about seventy-five feet in circumference, and about 2,510,000 square inches surface; comparatively will a large town be a very small speck on our globe.

II. It is well known, and may be tried, what continuing power is requisite in swinging a 24-pounder gun-ball, so as to describe in equal times proportionate distances round.

a centre. Considering now the earth a ball of 25,000 miles in circumference, of an amazing weight, revolving round the sun at a distance of 95,000,000 of miles,* it is difficult to form a just representation of the great and almighty Power which keeps our terrestrial ball moving, or which puts it in motion in immeasurable space. But still greater will our astonishment and our surprise become, if, in admiring such an omnipotent Power, we consider that besides our earth, likewise ten other planets, some about one thousand times as large as our earth, revolve round the sun, and that several of these planets have their satellites, each of these travelling in certain spaces round them in regular time.†

Sec. 8.—The following Table contains a brief representation of the numerical value, of the size, distance, densities, quantity of matter, revolution, inclination of orbits, inclination of axis, &c. of the planets :

* If a gun-ball, shot from a cannon, was to continue its swiftest course, it would require above twenty-four years to fly through 95,000,000 of miles.

† Considering the system of the world, no one will deny the thought, that such a power as mentioned must exist; and should this power not know the most secret of our actions, and the most secret of our thoughts?

Names of Planets.	Mean Diameters, English miles.	Mean distances from the Sun, English miles.	Mean apparent diameters seen from the Earth.	Diurnal rotations round their axis.	Tropical revolutions.	Sidereal revolutions.	Eccentricities, the mean distance = 100,000.	Inclination of orbits.
Sun . . .	883,246	-	min. sec. 32 1.5	Da. hrs. min. sec. 25 14 8	Yrs. da. hrs. min. sec. 87 23 14 32	Da. hrs. min. sec. 87 23 15 43	7,955	Deg. m. sec. 7 0 0
Mercury . . .	3,294	37,000,000	10	14 24 5 28	87 23 14 32	87 23 15 43	7,955	7 0 0
Venus . . .	7,687	68,000,000	58	1 23 20 54	224 16 41 27	224 16 49 10	298	30 23 35
Earth . . .	7,911 73	95,000,000	-	- - -	365 5 49 49 (perfolical revolution round the earth)	365 6 9 12	1,681.4	
Moon . . .	2,180	95,000,000 (240,000 from the earth.)	31 .9	29 17 44 3	27 7 43 5 round the earth)	27 7 43 12 round the earth.	-	5 9 3 (mean.)
Mars . . .	4,189	144,000,000	27	24 39 22	686 22 18 27	686 23 30 35	14,183	1 51
Vesta . . .	238	225,000,000	0.5	- - -	3 60 4	- - -	9,322	7 8 46 in 1800.
Juno . . .	1,425	252,000,000	3	- - -	4 128	- - -	25,096	13 4 in 1804.
Ceres . . .	1,024	263,000,000	6.4	- - -	1,681 12 9	- - -	8,141	10 37 in 1804.
Pallas . . .	2,099	265,000,000	6.5	- - -	- - -	1,703 16 48	24,630	34 50 40 do.
Jupiter . . .	89,170	490,000,000	39	9 55 37	4,330 14 39 2	4,332 14 27 10	25,013	1 18 56 in 1750.
Saturn . . .	79,042	900,000,000	18	10 16 2	10,746 19 16 15	10,759 1 51 1,12	53,640	2 29 30 in 1804.
Georgium Sidus .	35,112	1,800,000,000	3 54	- - -	39,637 4	36,737 18 0 0	90,804	0 46 20 in 1780.

Moon's synodical revolution 29 d. 12 h. 44 m. 12 s. round the earth in regard to the sun.

Sec. 9.—I. Although the distance of the farthest planet from the sun is considered 1,800,000,000 miles, it is still small comparatively to the distance of the fixed stars; and therefore if these are observed, the earth may, agreeably to the opinion of astronomers, be always supposed to be in the centre of the sky; and this is the reason why the terrestrial ball, placed in Apparatus III. within the transparent globe, may be considered as an explicative representation of the earth in the centre of the sky; particularly so, if we consider A, the earth, as a very small dot in the centre of the transparent ball, and the terrestrial globe, a many and numerous times enlarged representation of the small spot which is to substitute our earth; or B, the terrestrial globe, as our earth, and the transparent ball, as many and numerous times diminished or an approached representation of the celestial bodies, on a transparent ball near the earth.

II. All observations mentioned in this treatise are therefore, in A, supposed to have been made in the centre of the transparent globe, but in B on the surface of the terrestrial globe, supposing the sky, or the transparent ball, at a very great distance from it. Therefore the telescope used by an observer, and his place on the earth, and an arc in the sky measured by him, cannot be represented at the same time, and proportionately, on the apparatus; but the spot of an observer on the terrestrial globe, and the direction in which a ray of light may fall in his eye (being in the centre of our earth), can be shown, if it is supposed in using the Apparatus III, that the substitute of the observer is above, or without, or outside of the sky; and, according to this, the rays of light which fall in the eye of the observer on the surface of our earth, are represented by the prolongation of their directions, but negatively; or from the earth to the celestial body; which, as all directions are negative, makes no difference in calculation, as in spherics not the length of a degree of an arc, but the

number of degrees, minutes, &c. of an arc, are only to be considered.

IV.—GENERAL EXPLANATIONS AND DEFINITIONS.

Sec. 10.—Supposing any point on the surface of our earth as the place of an observer, such a point of the sky, which lies vertically, or in the direction of a lead line above it, is called the *zenith*, and the point diametrically opposite in the sky the *nadir*.

Sec. 11.—I. If the zenith and nadir are connected by a straight line, passing through the centre of the earth, and if a plane is laid perpendicularly on the said line, and through the said centre, it is called the *true horizon*. A plane almost parallel to the true horizon, or the disk of the sea round a person in a vessel, forms the *visible horizon*. Such a plane being, however, not a complete plane, allowance is to be made, according to the height of the eye of an observer above the sea, in making use of the visible horizon. A plane supposed through the eye of an observer, and placed perpendicularly on a lead or vertical line, but likewise parallel with the *true horizon*, is called the *natural horizon*.

II. The *artificial horizon* is a representation of the natural horizon, being parallel to the true horizon at the distance of half the diameter of the earth, or 3,955 miles, and the highest fixed star being an immeasurable distance from us, it may be said that both planes meet at an immeasurable distance, like parallel lines, and consequently they may be considered as the same plane in regard to the position of the fixed stars; and this again proves the assertion, in sec. 9, I and II, to be true.

III. The inhabitants of the earth under the nadir of a place are called the antipodes; they have the same true horizon with them under the zenith.

Sec. 12.—To an observer, a pure sky generally appears as a semi-globular vault of an immeasurable size, and the stars, seen on the vault of the sky, appear to him to revolve round an axis. This is however caused by the revolution of the earth round its *axis*. This axis is a supposed line, which meets the surface of our earth in two diametrically opposite points; they are called the *poles* of the earth. The zenith and nadir of the poles of our earth are the *poles of the world* in the sky.

Sec. 13.—A plane through the zenith and the sun's centre at twelve o'clock, or at noon, cuts the horizon in two points; one of them is the *south*, the other the *north* point. At equal distances from these two points, two others, diametrically opposite, are to be noticed; the one to the right hand of a person with his back to the south, is the morning or *east* point, that one to the left hand, the *evening*, or *west* point.

III. Between these principal or cardinal points in the horizon, lie others, as pointed out by any compass; the navigators generally take thirty-two points, equally distant, on the compass.

From these denominations, the *north-pole* and the *south-pole* of the earth, as well as the *northern hemisphere* and the *southern hemisphere*, take their denominations, which is best explained by Apparatus III, where the north and south pole of the terrestrial globe are named.

Sec. 14.—Any part of a large circle through the zenith or nadir of a place, perpendicular on the horizon, and containing ninety degrees from it, is called a *quadrant of altitude*. On it the height, or *altitude* and *zenithal distance* of celestial bodies, are counted in degrees, minutes, &c.

Sec. 15.—The *equator* is an imaginary large circle on the surface of the earth, every where equally, or ninety degrees distant from each pole; it separates the northern and southern hemispheres. A plane through the equator

cuts, apparently, the sky in a circle; it is called the *celestial equator*, or the *circle of right ascension*; it is likewise ninety degrees distant from the poles of the world, as shown by the metal circle round the transparent globe when this is moved round its axis. The equator and circle of right ascension are divided into degrees, minutes, &c.

Sec. 16.—Every large circle through the poles of the earth is called a *meridian*; it is perpendicular on the equator, and the zenith and nadir of every observer lie in a plane through it. A similar circle through the poles of the world is called the circle of *declination*; it meets likewise the circle of right ascension under right angles.

To represent any meridian, or any circle of declination, the division on the strong brass ring round the transparent globe is to be used. It may correspond with any point on the surface of the terrestrial globe, or on the transparent globe, and is therefore called the general meridian. *Sec. 2. IX.*

Sec. 17.—No meridian passes through any particularly distinguished point on the surface of the earth; therefore a first meridian may be taken from any point. The British, and most navigators, consider the first meridian through the observatory at Greenwich, the French through that of Paris, and most others from the isle of Ferro.

Sec. 18.—The *meridional line* is a line drawn from the north to the south, and produced by the line in which a plane through the meridian intersects the horizon, and consequently with inhabitants under the equator it is parallel to the axis of the earth.

Sec. 19.—I. Every place on the surface of the earth lies either in the equator, or at a certain distance from it. The shortest distance of a place from the equator, counted on a meridian in degrees, minutes, &c., is its *latitude*; it may extend from the equator to the north, or south, and is named accordingly.

II. The height or altitude of the pole is its shortest

distance from the horizon counted in degrees, &c. The altitude of the pole, and the latitude of a place, are always equal.

III. The *polar distance* of a place, is the complement of the latitude to ninety degrees, and is measured by an arc of the meridian of the place.

IV. All places equally distant from the pole or the equator, have equal latitude, and equal polar distance, and the pole has equal altitude above their horizon.

Sec. 20.—A circle through places of equal latitude, parallel to the equator, and at equal distance from the pole, is called a *parallel*, or a *circle of latitude*. Circles, parallel to the horizon, and at equal distance from the zenith, or of equal altitudes, are called *almucantaraths*.

Sec. 20.—I. The meridian of every place on the surface of the earth, meets the equator in one point: the distance of this point from another on the equator, where a first meridian intersects it, if counted on it in degrees, minutes, &c., is called the *longitude* of the place.

II. A plane through the first meridian, meets a plane through the meridian of any other place under a certain inclination; the inclination of the planes is called the *horary angle*, and is equal to, and measured by, the arc of the equator which lies between the points intersected by the planes of the two said meridians.

III. The equator being divided into 360 degrees, &c. may likewise, as the earth turns once round its axis in twenty-four hours, be divided into twenty-four hours. Every hour is therefore equal to fifteen degrees, $1^{\circ} = 4$ minutes in time, &c. Thus, by the known hour at one place, comparatively to the ascertained hour at any other place, may the difference of the hour, or of the degrees of longitude be found, which the terrestrial globe will show more fully by turning it, as the hours are indicated as well on the clock as on the division of the equator.

Sec. 21.—I. The *declination* of a celestial body in the

sky, is measured by an arc, in a similar manner to the geographical latitude of a place on the surface of the earth.

II. The *right ascension* of a celestial body is measured by an arc on the circle of right ascension, but from a certain point, as the first or 0° point on the celestial equator.

Sec. 23.—I. A plane through the arc of altitude of a celestial body, forming, with a plane through the zenith and the south point, an angle, which is called the *azimuth*; it is measured by an arc on the horizon, and is either east or west, and may be 180 degrees either way.

II. A plane through the arc of altitude of a celestial body, forming likewise an angle with a plane through the zenith at the west and east points of the horizon; it is called the *morning and evening distance*, or *amplitude*, and is measured by an arc in the horizon. It is north and south, and can therefore be never more than ninety degrees.

Sec. 24.—I. The *ecliptic* is a large circle in the sky, under an inclination of about 23.5 degrees on the equator. One half of it lies in the northern, and the other half in the southern hemisphere.

II. The earth moves in the plane of the ecliptic round the sun, while the earth's axis is perpendicular on the plane of the equator, and consequently inclined under the complement of the angle of the ecliptic, or about sixty-six and a half degrees on the plane of the ecliptic, and pointing meanwhile to one point in the sky.

III. The ecliptic is divided into twelve signs, or constellations, or imaginary configurations of stars, anciently invented to distinguish them; and each of these twelve parts contains thirty degrees.

IV. The celestial signs or constellations, or configurations of stars, have however changed their place, relatively to the intersections of the ecliptic and equator; but the names of constellations, in naming certain parts of the ecliptic

relatively to its intersection with the equator, remain as before.

V. The twelve signs of the ecliptic are :—

Aries	. . .	♈	the ram.
Taurus	. . .	♉	the bull.
Gemmini	. . .	♊	the twins.
Cancer	. . .	♋	the crab.
Leo	. . .	♌	the lion.
Virgo	. . .	♍	the virgin.
Libra	. . .	♎	the balance.
Scorpio	. . .	♏	the scorpion.
Sagittarius	. . .	♐	the archer.
Capricornus	. . .	♑	the goat.
Aquarius	. . .	♒	the water pourer.
Pisces	. . .	♓	the fishes.

VI. The change of the places of these constellations within about 2,200 years, when they were brought into use, is about one sign, or thirty degrees ; but still the beginning of Aries and Libra are considered the points of intersection of the ecliptic and equator ; they are counted from west to east in the sky, in the same direction as the earth turns round the sun.

VII. These points of intersection are called the *equinoctial points*, because when the sun appears to be in them, day and night are equal to every inhabitant on the surface of the earth. The point of intersection, when the sun apparently moves towards the northern hemisphere, is the *equinoctial of the spring* ; and the other, when the sun apparently moves towards the southern hemisphere, is the *equinoctial of the autumn* for the northern hemisphere.

Sec. 25.—I. The ecliptic has *two poles*, equally, or ninety degrees distant from it, like the equator.

II. Through these poles, at a distance of about 23.5 degrees from the pole of the equator, two circles are laid ; they are called *polar circles*.

III. These circles are likewise supposed to be on the surface of the earth, and likewise parallel to the equator, and about 66.5 degrees from it. Their greatest distance from the most remote point of the ecliptic is ninety degrees; and the diametrically opposite point on the ecliptic, or the highest point of the ecliptic, is $90 - 2 \times 23.5$, or about 33 degrees from them.

Sec. 26.—I. Two circles, parallel to the equator, and about 23.5 degrees from it, towards each of the poles, consequently through the most remote parts of the ecliptic from the equator, are called the *tropical circles*.

II. The sun is never seen more distant from the equator than 23.5 degrees. The tropical circle in the northern hemisphere is called the *tropic of the crab*, and that in the southern hemisphere the *tropic of the goat*.

III. The same tropical circles may likewise be represented on the surface of the earth, 23.5 degrees from, and parallel to, the terrestrial equator.

Sec. 27.—I. Through the intersection of the equator and the ecliptic, and the pole of the equator, a large circle is supposed to lie, it is called the *colure of the equinoctials*. One half of it, through the spring equinoctial point to both poles, is the *colure of the spring*, and the other half of it to the poles, the *colure of the autumn*.

II. Another colure, that of the *solstitials*, is laid through the equator and the ecliptic, where they are farthest distant from each other; but it is perpendicular on both, and intersects both in a distance of ninety degrees from the equinoctial colures. One half of it, through the summer solstitium, is called the *summer colure*, and the other half, between the two poles of the equator, the *winter colure*.

Sec. 28.—By the circles on the surface of the earth, mentioned in Sec. 26 and 27, it is divided into several rings or zones, viz. :—

I. The *torrid zones*, or the ring between the two tropics.

The sun is twice every year in the zenith of the inhabitants there, as his declination may be about 23.5 degrees.

II. The *temperate zones* lie between a polar and tropical circle: there is a northern and southern temperate zone, or one in each hemisphere.

III. The *cold zones* between the polar circles and the poles: there is likewise two of them, a northern and a southern one round each pole.

Sec. 29.—The *diurnal arcs*, or circles, are those in which the celestial bodies appear to move daily round the earth; those of the stars are parallel to the equator. The more these diurnal circles approach the pole, the smaller they appear to become, which will be explained by turning the transparent globe.

Sec. 30.—Every star, or a celestial body, passes once every day through the meridian. It is called the *culminating* of a celestial body. Stars which never set, or never rise for a place, have an *upper* and *lower culmination*.

Sec. 31.—The circle of *permanent occultation* of a place on the surface of the earth, lies ninety degrees distant from its zenith in the opposite hemisphere, and parallel to the equator. It is shown by that part of the horizon of a place which lies nearest to the pole in the opposite hemisphere, in turning it with the terrestrial globe in Apparatus III. It shows which of the celestial bodies can or may be seen from the place, and all such stars as do not rise above the horizon of a place, or which cannot be seen from there.

II. The circle through the stars (which never set or rise) is called the circle of *permanent apparition*. Apparatus III. proves, first, that from either of the poles, only the stars in the corresponding celestial hemispheres can be seen.

Secondly, that, from any part of the surface of the earth to the equator, only those can be seen, of which the sum of their declination in the opposite hemisphere, and that of the

latitude of the place, is not above ninety degrees, and, on the equator all celestial bodies are seen to rise and to set.

Sec. 32.—Large circles through the poles of the ecliptic, and perpendicularly on it, are called *circles of celestial latitude*; they are the same in regard to the ecliptic, as a meridian is to the equator on the surface of the earth.

Sec. 33.—The *longitude* of stars is measured in degrees, minutes, &c. on the ecliptic, from the point of the spring equinox to the intersection of the circle of celestial latitude with the ecliptic, and generally according to the signs, thus :—

0. Sign, or ♈ is 0°	VI. Sign, or ♊ is 180°
I. — — ♉ — 30°	VII. — — ♋ — 210°
II. — — ♊ — 60°	VIII. — — ♌ — 240°
III. — — ♋ — 90°	IX. — — ♍ — 270°
IV. — — ♌ — 120°	X. — — ♎ — 300°
V. — — ♍ — 150°	XI. — — ♏ — 330°

Sec. 34.—The zodiac is a part of the celestial sky, which, at each side of the equator, is included between two circles parallel to the ecliptic, and at a distance of ten degrees from it.

Sec. 35.—The earth revolving round the sun in the ecliptic, is always seen from the sun in the opposite direction, as the sun from the earth. Consequently, if the earth moves forward in the ecliptic, the sun will likewise appear to move forward; and thus originates the saying, respecting the sun's (*apparent*) motion, that the sun is in the 1st, 2d, and 3d sign, or in aries, taurus, gemmini, &c. of the ecliptic.

Sec. 36.—The *circles of the precession* of the poles are described round the poles of the ecliptic by the poles of the world. They lie at the distance of about 23.5 degrees round the pole of the ecliptic, and are described by the poles of the world round an axis between the poles of the ecliptic in about 26,000 years. This brings annually about

$\frac{5}{6}$ ths of a minute more in celestial longitude as the pole proceeds from east to west in the sky.

Sec. 37.—The time which the earth takes to revolve once round its own axis, so that the stars are again brought into the same position, is called a *sidereal day*; and the time which the earth takes to revolve round its axis, so that the sun again appears in the same position, is called a *solar day*: but as the sun appears always to advance every day a little in the sky, or in regard to the stars of the zodiac, as shown by the calendar of the sun's place in the ecliptic, a solar day will, by this reason, be longer than a sidereal day.

II. Both days are divided into twenty-four hours, each hour into sixty minutes, &c.; and taking the time according to the stars, it is called *sidereal time*; but according to the sun, it is called *apparent time*. The *mean* or *equated time*, is, however, that used in common life, and every twenty-four hours of every day are equal.

III. The difference of the mean time from the apparent or solar time, is called the *equation of time*.

Sec. 38.—A year is the time during which the earth revolves once round the sun, or during which the earth describes the orbit round the sun, or the time which is requisite to see the sun from the earth again in the same position in the sky, comparatively to the same stars. This is called a *sidereal year*; but as the stars move every year about $\frac{5}{6}$ ths of a minute in celestial longitude forward, it is of course somewhat longer than the year, when the sun is again in the same position, to the celestial equator; this is called the *tropical year*. *Sec. 36.*

V.—ON THE USE OF THE COSMOSPHERE FOR SOLVING PROBLEMS.

Sec. 39. I. THE dial-plate showing the hour at any place, is divided according to the astronomical day, beginning at twelve o'clock at noon, in twenty-four hours, or

in twice twelve hours, and like the common day, which, however, begins at twelve o'clock at night.

II.—The terrestrial globe which we inhabit, turns round its axis from the west to the east, or in the same direction as our earth describes its path round the sun, like all other planets. The dial-plate shows therefore the proper hour, if the terrestrial globe is turned in the proper direction from west to east; but if turned the other way, or from east to west, or in the opposite direction, the hour shown is always to be deducted from twelve, to show the right (sideral) time of the common day.

III. Whenever the place of the observer is brought under the meridian, the dial plate is always to be set so that XII. may lie to the south, and the same must be observed with the hand on the axis of the terrestrial globe, which must also point to XII.

Sec. 40.—I. The sun's place in the ecliptic at XII o'clock, or noon, for every day, is found in tables, and in the calendar for the sun's place near the corresponding day, and thus its declination is likewise ascertained. But the calendar for the sun's place in the ecliptic, on the stand of the apparatus, shows only mean years.

II. If the corresponding place of the ecliptic on the transparent globe be now brought exactly under the divided side of the meridian, by turning the transparent globe, the position of the sky for a given day at twelve o'clock will be shown; and the division on the meridian, which is over the said point of the ecliptic, will indicate the declination of the sun for the same time. If the place of the sun be given in tables according to a certain place, an allowance is to be made for another place which has not the same longitude, whether its time be before or after that of the said place, viz. in proportion to the given time from twelve o'clock at noon, taking twenty-four hours for the sun's apparent motion in twenty-four hours.

II. In fixing the centre of the tube of the axis of altitudes (marked by a point) over the said part of the ecliptic on the meridian, the declination of the sun for any day will be marked with more accuracy.

III. By fixing the tube of the axis of altitudes with its centre exactly over any celestial body, the declination of it will be marked by the point in the centre of the tube showing the number of degrees, &c. on the division of the meridian.

IV. In the same way will the declination of the zenith of any place on the surface of the terrestrial globe be found, if the point of the tube be set exactly over the pin in the small tube. The pin in the small tube in the pole of the horizon, which shows the place of an observer on the surface of the terrestrial globe, is always carefully to be placed over the corresponding spot of the observer (*Sec. 2, IV.*) on the terrestrial globe, so that the zenith may be shown with as much accuracy as possible.

V. To bring the pin in the small tube over the place of an observer on the surface of the terrestrial globe, and to place the horizon in a position to correspond with the said place of an observer, will be called, to *set the horizon* IV. To bring the meridian over a part of the transparent globe, which corresponds with noon, on a given day, will be called, to *set the sky*. To bring the tube of the axis of altitudes to mark the centre of the sun, or of a star, or the zenith, will be called, to *bring the tube of the axis of altitudes over the sun, or the star, or the zenith*. To place the hand on the dial at XII., and XII. to the south, if the observer's place on the terrestrial globe be under the meridian, will be called, to *set the clock*.

REMARK.—Any one who wishes to make use of the Cosmophere, must be perfectly acquainted *how the horizon is to be set, how the clock is to be set, how the sky is to be set, and how the tube of the axis of the altitudes is to be brought*

over the centre of the sun, over that of a star, and over the zenith; and being once familiar with this, all problems may with ease and dispatch be solved by a Cosmospere, and this instrument will become an interesting amusement, and be of great utility to navigators.

Sec. 41.—The rising and setting of the celestial bodies is explained, by supposing an observer on any place of the surface of the earth, as London for instance. Set the horizon, and the tube of the axis of altitudes, in the zenith of London, turn the transparent globe from the east to the west slowly, and it will be seen how the stars rise above the horizon, how they attain a great, the greatest and less height, and afterwards set again; other stars will attain a greater, the greatest, a less and the least height, and never set nor rise, but be always over the horizon; and others will never come above the horizon; and thus the parallel motion of the stars with the equator is clearly explained. Then leave the transparent globe stationary, and put the terrestrial globe in a slow motion from the west to the east, and the appearances will be the same as above explained. If the hand of the clock is meanwhile examined, it will be seen, that different stars attain their greatest, or least, or proportionate height, until all come in their former position, while the hand on the dial points to the same hour, after a complete revolution of the globe.

Sec. 42.—Considering now the sky comparatively to the different points, it will result I., that if the tube of the axis of the altitudes be set over 0° declination, and the terrestrial ball turned, some stars will rise perpendicularly on the horizon, pass the zenith, and set perpendicularly; but the rest will rise, pass the meridian, or culminate, and set parallel to the first mentioned: all stars will be visible there at some period, and the polar stars will always remain in the horizon.

II. But if the observer be supposed in the pole, and the

transparent ball turned, then all the stars that are visible will be seen moving round, and parallel with the horizon ; consequently, none of the stars will set or rise ; but only one half of them, or those to the equator, can be seen from either of the poles.

III. If, however, the observer is supposed between the equator and either of the poles, and the tube of the axis of altitudes is set in his zenith, then only the stars to the corresponding circle of permanent occultation will be visible to him at some period ; consequently, all the stars in the hemisphere in which the observer is situated, and those which are not above ninety degrees from his zenith, as will be shown best by the quadrant of altitude, if one of them be put under the meridian while the transparent globe is turned. All stars will rise to this observer in an inclined direction ; some will describe only small arcs above the horizon, others larger, and others again in the same hemisphere with the observer near the pole, (but never more than 90 degrees distant from the zenith, or above the circle of permanent apparition,) will never set : this will be the case when the observer is in the northern or southern hemisphere.

Sec. 43.—The sun being stationary, and the earth moving round, both will, as mentioned in *Sec. 35*, be seen diametrically opposite in the sky to each other ; and thus will the sun appear to move every following day near other stars to the eastward : as however the stars cannot be seen until after the sun is some degrees below the horizon, other stars will be seen every following day ; they will appear in the east after sunset. This is clearly explained by bringing the place of the sun in the ecliptic for several following days, at noon, under the meridian, then turning the terrestrial globe till the sun is in the west part of the horizon, and observing the stars which will come every following day in the horizon. By bringing the observer, always at noon the following day, under the meridian of the sun's centre in the ecliptic, the

stars in the horizon, and those which culminate the following day, will likewise be always more to the west than the day before; and on the midnight of every following day the stars will likewise appear to have progressively advanced. Thus will every star have a different position, in respect to the horizon of a place, at the same hour every following day, and likewise every cluster or number of stars in the milky way.

After the end of a year, the same appearances will, in regard to time, take place again; and thus the place of any star, at any time, of every day may be easily found.

Sec. 44.—From this explanation it results, that the place of a given star, at a given time, for a certain day on a certain place, is found in the following manner :—

I. Set the horizon, set the sky, set the clock, bring the observer under the meridian, and set the tube of the axis of altitudes over the zenith. *Sec. 40.*

II. Turn the terrestrial globe till the hand points to the given hour, *Sec. 39.* Bring the zenith of the observer on the transparent globe, under the meridian; then a quadrant of altitude will mark the altitude of the star, and the point where it meets the horizon will show its amplitude and azimuth.

Sec. 45.—If the time of a known place on the earth be given, the hour of any other given place on the surface of the earth may be found as described in *Sec. 44.*

I. Set the horizon to the first place, bring the observer under the meridian, and set the clock to the given time of the first place, *Sec. 40.*

II. Turn the terrestrial globe until the other place will be under the meridian; the clock will show the difference of time, *Sec. 39.*

Sec. 46.—From places on the earth which have the same latitude, the same stars will be daily seen earlier or later, according to the situation, if more to the east or to

the west, *Sec. 42.* This is shown by fixing the tube of the axis of altitudes in the proper latitude, and turning the terrestrial globe slowly, and observing the hand of the clock: it will be seen that a place more to the east will come sooner under the general meridian, if this and the transparent ball be kept steady; and of course the stars culminate sooner in a place more to the east; and the contrary, if more to the west.

Sec. 47.—The sun's place over the horizon of an observer, at a given time on a certain day, is found as follows:—

I. Set the horizon, set the sky, set the clock, and bring the tube of the axis of altitudes over the sun's proper place or declination, *Sec. 40.*

II. Turn the globe to a given hour, (*Secs. 39 and 45,*) and a quadrant of altitude will show the sun's altitude; and on the horizon the azimuth and amplitude will be shown by the right-angular intersection of the quadrant and the horizon.

Sec. 48.—The hour of a day, when a star will have a certain altitude over the horizon of an observer, is found in the following manner:—

I. Set the horizon, set the sky, set the clock, bring the observer under the meridian, and set the tube of the axis of altitudes in the zenith of the observer.

II. Turn the transparent globe until the star have the given altitude, then the hand on the dial-plate will show the hour required before or after noon: on the horizon the amplitude and azimuth are marked by the quadrant of altitude.

Sec. 49. Thus it may be found when a star will culminate, or be the highest over the horizon, and when it will rise and set on any given day.

Sec. 50.—The finding the time when the sun, on a given day, will be seen by an observer under a certain altitude, is done as described in *Sec. 48* with a star, supposing the sun to have his proper place in the ecliptic; and in a similar

manner the time of the sun's rising and setting will be found.

Sec. 51.—Supposing the sun in the solstitium of summer, it will be seen that he is nighest to the zenith of any point of the northern terrestrial zones, and farthest from the zenith of the inhabitants in the southern zones, and *vice versâ*.

Sec. 52.—I. The sun having, during a year, each day a different altitude at noon, it will of course have, in rising and setting daily, a different amplitude and azimuth, which is shown by bringing the tube of the axis of altitudes over the sun's centre, according to his place in the ecliptic for several following days, (*Sec. 47,*) and turning the transparent globe, so that the sun's place may pass the horizon in rising and setting: it will be found that the sun will rise and set only twice every year in due east and due west, or when he has no declination, or is in the zenith of the inhabitants of the equator.

II. The sun's declination changes every day between the tropics, and he will be twice every year as well in the zenith of the inhabitants of the tropical zones as over the equator: this happens when the declination of the sun is equal to the latitude of the place on the earth.

III. The sun's declination decreases always after attaining the tropics, and he will therefore never be in the zenith of other inhabitants but those of the tropical zones, as his declination is never more than the latitude of a tropic.

IV. Supposing the declination of the sun to have been 0 degrees, or to have been in the equator, and moving towards a pole, then he will be constantly seen, and neither set nor rise to the inhabitants of the polar zone round this pole, (the zenith of which is not above ninety degrees distant from the sun,) until he returns, and his declination gets less; and if the sun arrives in a tropic,

he will always be seen, and neither set nor rise to the inhabitants of the corresponding polar zone; but at the same time he will not be seen, and neither rise nor set to those in the opposite polar zone, (the zenith of which is above ninety degrees from him,) till his declination decreases, or until he again approaches the other pole.

V. This will be best explained by bringing the tube of the axis of altitudes over the sun's place, or in its declination for the said days; and then the quadrants of altitude will show those parts of the earth which are illuminated by the sun, as only one-half of the earth can be illuminated at a time by the sun.

VI. If the sun be in the equator, it will likewise illuminate one-half of the globe, to both the poles: then all the inhabitants of the earth will have twelve hours day and twelve hours night.

Sec. 53.—I. The sidereal day (explained by Apparatus III, *Sec. 37*,) being the interval of time which our earth takes to turn round its axis, or the time which passes from the moment that a star is under our meridian, or culminates, until its next culmination, or until it again come under the meridian, is not so long as a solar day, as the sun appears meanwhile to have made a little progress in the sky; and taking therefore the time from the sun's culmination to his next culmination, or his passing the meridian again, or a solar day, it is but little longer than a star day. *Sec. 37.*

II. All the sidereal days are of equal length; but as the earth does not move with equal velocity, and as it does not pass through equal parts of the ecliptic in equal times round the sun, he appears not to advance every day an equal distance. He appears to advance, for instance, in the beginning of July only about 57 minutes, but in January about 61 minutes, in the ecliptic. The mean of both is 59 minutes 30 seconds of an arc; but this arc of the ecliptic is equal to 59 minutes 8 seconds of an arc on the equator,

where the angle of the hour is measured. From this results difference between mean and true solar days.

III. A mean solar day is consequently the time in which all the equator, and 59 minutes and 8 seconds, or 360 degrees 59 minutes and 8 seconds, pass the meridian.

IV. As, however, 59 minutes 8 seconds of an arc of the equator correspond with one-fifteenth of it, or 3 minutes 56 seconds in time, a mean solar day will be 3 minutes 56 seconds in time longer than a star day, and therefore will a sidereal day only have $23^h 56' 4''$ of mean solar time: and according to this mean solar time, common or equated time is regulated. Sec. 37.

Sec. 54.—I. The time of an observer to the east, from a given place, is before, and that of another more to the west, from a given place, is after the time of the first place, as our terrestrial globe turns from the west to the east round its axis, and as the celestial bodies appear to move from the east to the west. This is explained by turning the terrestrial globe round its axis from the east to the west, as 360 degrees on the equator will make 24 hours. Sec. 45.

II. Any one travelling 360 degrees from the west to the east, will count therefore 360 degrees less, or 24 hours earlier, or a day less; and, on the contrary, any one travelling 360 degrees from the east to the west, will count one day more than is counted on the place from whence he set out, as one hour in time is always to be counted for every 15 degrees to the east or to the west.

Sec. 55.—1. The motion of the moon may be explained by the Apparatus II. It moves round the earth in the time in which the earth proceeds about 27.75 degrees, which gives $\frac{360}{27.75}$, or nearly 13 revolutions of the moon round the earth within one year.

II. The moon moves however not in the same orbit round the earth, in which the earth revolves round the sun.

The plane of the moon's orbit is inclined about 5.4 degrees on the plane of the ecliptic, while the moon's orbit is cut by the ecliptic in two equal parts.

III. The intersections of the moon's orbit by the plane of the ecliptic are called *the nodes*, and the line uniting them the *line of nodes*. The one node, when the moon enters the northern part of his orbit, is called the *ascending node*, and is marked thus Ω ; the other node, when the moon passes the ecliptic, and enters the southern hemisphere, is called the *descending node*, and is marked thus $\mathcal{V}$.

III. The places of the moon's nodes, and the line of nodes of the moon are variable; they move backwards, from the east to the west, in the zodiac, but come every 19 years to the same spot again.

IV. The ecliptic being inclined about 23.5 degrees on the equator, and the moon's orbit about 5.4 degrees on the ecliptic, she never will obtain a greater declination from the equator than nearly $23.5 + 5.4 = 28.9$ degrees.

Sec. 56.—I. The diurnal arcs of the moon are, like those of the sun, the largest in respective hemispheres when its corresponding declination is the greatest.

II. If the moon is opposite the sun, her illuminated side is seen from the earth; but if in the direction of the sun, its dark side is seen. The first is called full moon, and the latter new moon; and when the moon is in either place, she is said to be in her *syzigies*. But if at 90 degrees, or at an equal distance from the place of full moon, or new moon, or when one-half of her is seen to be illuminated, she is said to be in her *quadratures*.

III. If the moon's orbit lay in the plane of the ecliptic, she would, during the time of a full moon, be in the opposite direction, and in the time of a new moon in the same direction as the sun, and consequently describe as a

new moon in summer the diurnal arc which the sun describes, but in winter as a full moon the diurnal arc which the sun describes in summer; consequently will the moon describe in winter as a new moon, in the hemisphere where the sun is, but as a full moon in the opposite hemisphere, the largest diurnal arcs; the contrary will be the case in summer, and is true for either of the hemispheres.

IV. The declination of the moon being sometimes larger than that of the sun, when equally distant from her nodes, will cause her to describe larger diurnal arcs than the sun, when near a full moon in the opposite hemisphere where the sun is, and during a new moon in the same hemisphere with the sun; and from this it results, that a full moon shines in this case considerably longer in the winter than in the summer months in either of the hemispheres; but as the inclination of the orbits of the sun and the moon never deviate above 5.4 degrees, this will always be the case.

V. Such places, consequently, as lie nigher the pole than the moon's declination during a full moon, will at this time see her continually for several days, while others on the opposite side of the earth do not see her at all; as was explained in Sec. 51, for the sun.

VI. Astronomical calendars and ephemeris give the right ascension and declination of the moon, for each day at noon, for a certain place. This serves to find the moon's diurnal arc for places of the same longitude,* and the time of her rising and setting for any day, by marking her place for the day on the transparent globe; next, bring the proper place of the terrestrial globe under the meridian; set the sky and the clock, turn the transparent ball until

* If places of different longitude are given, the proportional progress of the moon in her orbit is to be taken into consideration. For instance, if the moon moves twelve degrees forward in her orbit in twenty-four hours, half a degree is taken less for each fifteen degrees to the east, and, the contrary, more, if to the west.

the moon's place is under the meridian, and bring the tube of the axis of altitudes over the moon; then the quadrants will mark the part of the terrestrial globe from which the moon will be seen at any hour; and having set the horizon, her diurnal arcs, and the time of her setting and rising, are found similarly as with a star or the sun.

Sec. 57.—I. The phases of the moon may be explained by Apparatus II. The sun, or the ball in the centre, being the luminous body which illuminates the earth and moon, can only take this effect on one half of each of them. If therefore the moon is between the sun and the earth, or if it is a new moon, her illuminated side cannot be seen from the earth; and on the contrary, if the earth is between the sun and moon, then the illuminated side of the latter is turned towards the earth, and can completely be seen from here.

II. The moon revolving likewise round the earth in the same direction as the earth round her axis, and round the sun, will, of course, if any day in the direction of the sun, as the moon's motion is more accelerated than that of the earth, or than the apparent motion of the sun, appear the next day more to the east of the sun, and will consequently rise later, and set later every day than the sun. Some days after a new moon, its edge on the right side will be seen; and about seven days after a new moon, one quarter of its surface will be visible: this is called the *first quarter* of the moon. The moon is now about ninety degrees distant from the sun, and passes then, at six o'clock, the meridian.

III. If the moon moves on, after several days, the illuminated part or phase of her will be larger still, until 180 degrees distant from the sun, or until a full moon. Now it will rise nearly opposite to the place where the sun sets, and set nearly opposite where it rises; and will consequently describe (in winter) a larger arc above the horizon, in the

hemisphere which is opposite to that over which the sun is seen. Sec. 56, V.

IV. After a full moon, she approaches again towards the sun, until ninety degrees from him, when only one half of the moon, or its left side, is illuminated ; which is called the *third quarter*. And thus her phase gets smaller again until new moon.

Sec. 58.—I. The time from a full moon, or new moon, to the next, is called a *synodical month*; its time 29 days, 12 hours, 44 minutes, and 12 seconds.

II. A *sidereal month* is, however, the time which passes from the moment in which the moon leaves a fixed star, until she comes to it again ; but a *periodical month* is the time during which she completes her orbit in regard to a place in the sky, in considering the precession of the stars at the same time. Sec. 36.

III. If therefore the earth were stationary, the periodical month would be equal to a synodical month : as, however, the earth moves about 29.25 degrees forward in her orbit, during the time in which the moon revolves round her ; and consequently, as the sun's apparent motion during this time is the same, the moon will be seen sooner in the direction of the star, than in the direction of the sun, if she left both when they were in the same direction.

IV. The moon will be 2 days, 5 hours, 1 minute sooner near a fixed star, which she left when the sun was near the fixed star, than near the sun. This difference of a synodical month from a sidereal month, gives the length of a sidereal month 27 days, 7 hours, 43 minutes, 12 seconds ; while that of a periodical month is 27 days, 7 hours, 43 minutes, 5 seconds.

V. It may be explained by Apparatus II, in tracing the moon's orbit on the transparent globe, and noticing the

place where the sun was seen near the moon and a star ; but making good for the sun's apparent motion during 29.5 days, it will prove that the moon is sooner seen in the direction of a star, than in that of the sun. The lunarium also proves the same, if the earth has advanced 29.25 degrees, when the moon comes in the same direction in regard to the sun.

Sec. 59.—I. Eclipses are phenomenas caused by a planet or a satellite, viz. when either the planet is in a line between the sun and the satellite, or when the satellite is in a line between the sun and the planet ; but the expression 'eclipse' is generally only used in regard to the sun and moon.

II. An eclipse can only take place when the moon is in its node, or when its orbit intersects that of the earth ; consequently, an eclipse of the moon can only be seen during the time of a full moon, or when the earth is between the sun and the moon ; and an eclipse of the sun can only be seen during a new moon, or when the moon is between the earth and the sun.

III. The shade thrown by the earth and the moon, they both being smaller than the sun, has the shape of a cone, the foot of which is equal to a section through the earth or moon's centre.

IV. Whenever the moon comes in the shade thrown by the earth, or the earth in the shade thrown by the moon, either of them will be eclipsed, or be deprived of the light from the sun, as far as they, or parts of them, enter the shade of the other.

V. If the moon is completely with his nucleus before the sun, it is a *total eclipse of the sun* ; if, however, only a part of the shade, or half of the shade, meets a part of the earth, it is said to be a *partial eclipse of the sun*. But if the shade of the moon does not meet the earth at all, but

the moon be in a line with the sun, then it is said to be a *ring-shaped eclipse*, which, however, will only be seen from those places over which the shade of the nucleus and the half shade passes.

VI. Those inhabitants of the earth which come first in the cone of the moon's shade, will see the eclipse first, and others later; those which do not come in it at all, will not see the eclipse, like those to whom the moon is not visible during the eclipse.

VII. The same as the sun, the moon may be eclipsed; but as the cone of the shade of the earth is much larger than that of the sun, lunar eclipses will happen more frequently than solar eclipses.

VIII. The eclipses mentioned in astronomical works have been calculated so as to correspond to the place for which they are made. As however the time of places which are not under the same meridian differs, (Sec. 45,) there is always an allowance to be made to the west or east of them, in regard to eclipses mentioned in such annually published astronomical tables, answering only for a certain place.

IX. The lunar, as well as the solar eclipses, will only be visible to such as have the moon or the sun over their horizon during the eclipse. All common calendars which take the time of the eclipse from an annually published astronomical ephemeris for a certain place, ought, first, to make allowance for the time, whether a place be more to the east or west; and, secondly, it should be considered if the moon or sun be visible, as a lunar or solar eclipse may begin or happen while the moon or sun is not visible.

X. Eclipses may be found by Apparatus II., by marking the moon's and sun's place on the transparent globe during the time of a full or a new moon. If the place of the sun and moon is at the same time in one point of the sky, a solar eclipse, and if their places are 180 degrees distant

or opposite to each other, a lunar eclipse will happen, and thus may common calendars be corrected according to different places.

XI. The eclipses of the moon and sun can only be seen by the inhabitants of the earth, first, in whose zenith she is, and secondly, by those which are not above ninety degrees from them, which is best pointed out after marking the place of the moon, during an eclipse, by bringing her place for the time, (to be found in astronomical tables,) under the meridian, setting the sky, setting the clock, (Sect. 40,) and fixing the tube of the axis of altitudes over the moon's or sun's centre, according to the eclipse, whether lunar or solar. The 0 points of the quadrants of altitude will then show, if the terrestrial globe be properly turned, from which part of the earth the eclipse may be seen.

Sec. 60.—As an eclipse of the moon begins at a certain time, and as it is seen at different places on the earth, of course, at the same moment, but according to their longitude and respective time, the longitude of a place may be calculated, if the proper sidereal or apparent time of the beginning and end of an eclipse, the emersion and immersion of the brim of the moon and the shade, or of the shade of the earth on the moon, be correctly observed.

Sec. 61.—The seasons on the earth, summer, winter, spring, and autumn, are best explained by Apparatus II. The four small balls round the centre ball are to represent the earth, each having, by a thin marked wire, the directions of the earth's axis. It is always inclined under the same angle on the ecliptic; and the direction of this axis is always the same, or from one pole of the world to the other.

II. Supposing, now, the earth in the direction where her axis towards the pole lies inclined, and pointing in a direction contrary to that of the sun; then the angle formed at the centre of the earth, by the axis of the earth to the

north pole, and by a line from the earth's centre to the sun's centre, will be the largest. The axis of the earth towards the south pole, will meanwhile incline in the same direction as the sun, and form the smallest angle at the centre of the earth, by the axis of the earth to the south pole, and a line from the centre of the earth to the sun's centre. The sum of both angles, or of the angle formed by the northern part of the axis with the line from the centre of the earth to the sun, and of the angle formed by this line, and by the southern axis of the earth, are 180 degrees, as the angles on a straight line, or on the axis of the world. The sun illuminating now only one-half of the earth, will of course in this case illuminate the surface of the earth, ninety degrees round the point of intersection on the surface of the earth, with a line from the earth's centre to that of the sun.

III. The inclination of the axis of the world, or of the earth, on the plane of the ecliptic, is about 66.5 degrees; but the angle formed by the said axis, and by the direction from the earth's centre to the sun, is about $180 - 66.5 = 90 + 23.5 = 113.5$ degrees. The sun will therefore, some time or other, if he is in the southern hemisphere of the sky, and 113.5 degrees distant from the north pole, not illuminate any part of the northern polar zone, or all parts of our globe not above 23.5 degrees from the north pole. Meanwhile, the sun will, (as the inclination of the axis of the earth, with the direction from the centre of the earth to the sun, forms in the southern hemisphere an angle of 66.5 degrees,) illuminate the surface of the earth 23.5 degrees farther than the south pole, or not set for the southern polar zone. And the same is the case if north is taken for south, and south for north.

IV. If the sun forms with either the southern or northern axis the smallest angle, it is said to be nearest to the corresponding pole, and to be summer in the corresponding

hemisphere ; but if the sun forms the greatest angle with either the southern or northern axis, it is said to be farthest from the corresponding pole, and to be winter in the corresponding hemisphere.

V. If the earth is ninety degrees more advanced from the position just mentioned, her axis is still parallel to its first position, and inclined under the same angle on the ecliptic. But a line from the centre of the earth to that of the sun, is now perpendicular on that line, traced from the earth's centre to that of the sun, when the earth was ninety degrees from this place, and consequently the earth's axis will now be perpendicular on a line from the earth's centre to that of the sun. The same will be the case when the earth is ninety degrees on either side of the first-mentioned positions, III. IV.

VI. In this case, the sun will, as before, illuminate likewise one-half of the earth, and be seen from all parts on the surface of the earth which are not above ninety degrees from the intersection on the surface of the earth, with a line from the centre of the earth to that of the sun : and of course the sun will illuminate the earth to the poles. The seasons, when this happens, are the beginning of spring and autumn, viz. spring for the hemisphere, where summer will follow ; and autumn for the other.

VII. The northern axis of the earth will, in moving this body from the winter solstitium for the northern hemisphere to the east, always form a smaller angle with a line from the centre of the earth to that of the sun, until this angle is ninety degrees ; and from here again, until the inclination of the same lines will be 66.5 degrees, when the northern hemisphere will be in the beginning of summer.

VIII. From here, or the beginning of summer, the inclination of the northern axis of the earth, with the direction from the centre of the earth to that of the sun, will increase, while she moves forward in her orbit, until

the inclination becomes ninety degrees, when autumn begins; and considering the earth to move on, the inclination of the northern axis of the earth, with the direction from the centre of the earth to that of the sun, will still increase, until it becomes about 113.5 degrees, when the winter begins for the northern hemisphere.

IX. Every particular which has been mentioned here in regard to the northern hemisphere is equally applicable to the southern hemisphere. And both may be explained more fully, in regard to the length of the days, by bringing the tube of the axis of altitude over the different places of the sun, and finding which part he illuminates, and which diurnal arcs he describes. (Sec. 40.) Apparatus III.

X. These explanations may equally well be made by a terrestrial globe being taken out of the transparent ball, and being moved round a light, while the axis of the terrestrial globe is to be directed always to the same point of the room, supposing this point to be the north or south pole of the sky.

Sec. 62.—I. From this it results, and may be seen by Apparatus III. that the antipodes having always twelve hours difference in their clock, from being 180 degrees in longitude distant from each other, have likewise exactly the contrary seasons.

II. That the inhabitants on the opposite sides of a zone have the same seasons, but twelve hours difference in time.

III. That the inhabitants under the same meridian, but opposite zones, have the same time of the day, but opposite seasons.

Sec. 63.—Taking the situation of the sun, and the shade of the inhabitants, it results likewise from the above, that,

I. The inhabitants of the tropical zones have the sun over their head, or have a shade towards the north or the south, according to the position of the sun.

II. That the inhabitants of the temperate zones have a shade towards their pole.

III. That the inhabitants of the polar zones have a shade at certain periods in every direction round them.

Sec. 63.—I. It has been observed, that the axis of the earth does not continually point to the same part of the sky, (Sec. 36,) or that the point of the prolongation of the earth's axis in the sky changes its position round the pole of the ecliptic within about 259,000 years, which is called *the great Platonic year of the world*. This is caused by the action of the moon and sun, but in a retrograde direction, or the same as the moon's line of nodes moves from east to west.

II. The manner in which the point in the sky, where the prolongation of the axis of the earth meets it, changes its place annually about 50.2 seconds of an arc, is explained, and is shown by the moveable ring, with the semi-ring fixed to it, being put with the hole for the ecliptic over its pole, and in being moved with the pole of the equator round the pole of the ecliptic. The equator will then change its position in regard to the ecliptic, or it will move on in the sky from the east to the west, while the equinoctial points remain on the ecliptic; and consequently the equator will recede on the ecliptic, while the longitude of the celestial bodies increases. The circle of the ecliptic, however, not altering its situation in regard to the pole, will cause no change in the latitude of the celestial bodies.

Sec. 64.—I. The place of the planets in the sky, as seen from the sun, is called their *heliocentrical place*; but their place in the sky, as seen from the earth, is called their *geocentrical place*.

II. If one planet is diametrically opposite, or 180 degrees distant from another, and the sun between them, they are said to be in *opposition*, and it is marked $\odot$; but if planets seen from the sun, appear to be in the same part of the

ecliptic, they are said to be in *conjunction*, and are marked thus 8.

III. The upper planets, (those nearer the sun,) can, however, never be in opposition with the sun, in regard to the lower planets, or those farther distant from the sun; consequently neither Mercury nor Venus can be in opposition with the sun, as seen from the earth, as they never will be 180 degrees distant from the sun.

Sec. 65.—The earth, not being a complete globe, but having a greater diameter near the equator than between the poles, is retarded in the direction of the ecliptic by the attraction and the motion of the moon and the sun, similarly as the moon's nodes move backward or recede, (Sect. 63.) By this the *precession* is created. But whenever the moon and sun are not in the equator, they have another action on the earth's redundant matter round the equator, in attracting this part more than the pole, by which the axis of the earth is caused to describe a small curve round the pole. This deviation of the axis of the earth is called the *nutation* of the earth's axis. Its period is ten years, when it is the same again as before. Its greatest influence is about eighteen seconds of an arc, and therefore only in calculations which require great nicety is it taken into account. Works on astronomy give tables for this purpose.

Sec. 66.—I. It is well known in natural philosophy, that a ray of light falling into a denser transparent matter, is deflected towards the earth's centre; and in the same manner will the rays of light from any celestial body be bent in coming near the earth, as it is surrounded by an atmosphere, or by air, or an invisible elastic fluid, which always gets thinner and lighter at a greater distance from the earth. This bending of a ray from a celestial body is termed *refraction*.

II. The refraction of a ray makes every celestial body always appear higher above the horizon than its real posi-

tion is ; there is, therefore, to be deducted a certain quantity in observing the altitudes of all celestial bodies. The tables of refraction, in works on astronomy, give the respective quantity to be deducted under certain circumstances.

Sec. 67.—I. Besides the corrections mentioned, which, in observing celestial bodies are to be considered, and to be taken into calculation, there is likewise the swiftness of light, in comparison to the motion of the earth, to be considered, as a ray of light coming from a celestial body will require some time to pass through a telescope, while this is moving on in the direction of, and with the swiftness of the earth's motion.

II. A telescope, through which a star is seen, lies therefore not exactly in the direction of the ray of light from a celestial body, but is inclined under an angle formed by two lines representing the swiftness of a ray of light, and the earth's motion.

III. If a star is to be observed by a telescope, this is not to be pointed exactly in the direction of the star, but as a gun would be to hit a bird flying. But as the velocity of the light which passes in eight minutes and seven seconds from the sun to the earth, is 10.313 greater than that of the earth, the angle under which the telescope is to be pointed will deviate very little from the true one, and is only, when largest, twenty seconds. This angle is called the *aberration* of a star. Astronomical tables give the aberration for certain places, and under various circumstances.

Sec. 68.—I. An angle, the vertex of which lies in the centre of a celestial body, and which is formed by two lines from it, one to the centre of the earth, and the other to the surface of the earth, so as to be a tangent, and which angle lies consequently between the two said lines, is subtended by a semi-diameter of the earth, and is called the *parallax*.

II. All celestial bodies, like the sun, the moon, and the planets, have a parallax, which is to be taken into calculation, as they do not appear from the surface of the earth to be in the same position in the sky in which they would be seen from the centre of the earth.

III. This parallactic angle makes such a celestial body appear to have a less height than it really has, if seen from the earth's centre; and the quantity of it is therefore additive to a measured altitude.

IV. This parallactic angle always vanishes when the celestial body is in the zenith, as it then lies in the direction of the observer, and the centre of the earth. It is largest in the horizon, as the lines forming this angle are then subtended by the earth's semi-diameter under a right angle. But when the celestial body has a greater height, this parallactic angle diminishes, because the subtended line, or the earth's axis, then lies more inclined to the lines by which the parallactic angle is formed.

VII.—ON THE SOLVING OF PROBLEMS BY THE COSMOSPHERE.

Sec. 69.—To find the right ascension of the zenith of a given place.

I. Set the horizon, set the sky, set the clock, and bring the observer under the meridian. *Sec. 40.*

II. Turn the terrestrial globe until the given hour is shown by the clock, or on the equator, (*Sec. 39.*) taking fifteen degrees of longitude for one hour.

Then the zenith of the place will be exactly over it, and the corresponding point of the equator of the transparent ball will show the right ascension; which is best found by bringing the zenith under the meridian, and observing the corresponding degrees under the divided side of the meridian.

Remark 1. The point of the zenith of a certain place for a given time, ought always, if brought in use afterwards, to be traced on a piece of glass paper, stuck by moistening it a little, and pressing it under a temperature of about twenty degrees Reaumur, to the outside of the transparent globe. The exact place of the zenith, or a celestial body, is to be marked on it by two small cross lines drawn by a fine point.

Remark 2. Should the place of the sun, or of a star, be traced on the surface of the transparent globe, for solving problems, it ought always to be marked in this manner; for suppose their places are not correctly marked, or not according to precession, &c. then no great accuracy may be expected. The stars which have been marked on the transparent globe, serve only as a guidance in finding a star. The precession of the stars is always given according to a certain time, and ought always to be considered; and besides the error caused by this, the refraction of the glass will increase it; but both ought to be avoided.

Sec. 70. To find the diurnal arc of a certain star for a place whose latitude is known.

I. Set the horizon, bring the observer under the meridian, bring the star in the horizon, and set the clock. *Sec. 40.*

II Turn the transparent globe till the star culminates; then the hand, as well as the difference of degrees on the equator under the meridian, divided by fifteen, will show the time of half the diurnal arc.

Sec. 71. To find the diurnal arc of the sun for a given place on a given day.

Remark. In mentioning the sun or moon, their centre equally distant from the brim is always meant. The diameter of both, for different times, is found in astronomical tables.

I. Set the horizon, set the sky, set the clock, and bring the observer under the meridian. *Sec. 40.*

II. Turn the transparent globe until it meets the horizon, in the west or in the east; then the hour, or the difference of degrees on the equator under the meridian, divided by fifteen, will show half the diurnal arc.*

Remark. The diurnal arc of the moon is found in a similar manner.

Sec. 72. To know the name of a certain star seen above the horizon from a place whose latitude is known.

I. Set the horizon, set the clock, set the sky, and bring the observer under the meridian. Sec. 40.

II. Turn the terrestrial globe until the clock mark the given time.

III. Keep the place of the observer on the terrestrial globe, with the transparent globe, firm in the same position.

IV. Turn the instrument according to the compass; that south of the Cosmosphere lies towards the south point of the observer. Then will a star on the transparent globe, the place of which corresponds with the one seen in the sky, be the star required.

V. If, however, the altitude and the azimuth of the star are known, bring the tube of the axis of altitudes over the zenith of the observer. Then the quadrant of altitude, having the corresponding altitude marked on it, and being put with the point nod in the proper azimuth, will show the star, and its name on the Cosmosphere.

Sec. 73. To find the culminating, rising, or setting of a star for a certain place. Secs. 49 and 70.

I. Set the horizon, set the sky, set the clock, and bring the observer under the meridian. Sec. 40.

* Taking this question strictly, the place of the sun, or moon, is to be set according to the longitude of the place, (Sec. 40); and as the sun or moon occupies a different place in the ecliptic in the morning, from what it did at noon, or in the evening, allowance is to be made for this. Besides, refraction and parallax will make the sun appear as if in the horizon, while it is about thirty minutes under it.

II. Turn the terrestrial globe until the star culminate, set, or rise; and the time shown by the clock, or the difference of degrees on the equator under the meridian, divided by fifteen, will be the hour required.

III. The place of a star may thus, by turning the terrestrial globe, be pointed out at any time; and its azimuth, amplitude, and altitude, be found in the horizon, and on the quadrants of altitude, by bringing the tube of the axis of altitudes over the zenith of an observer, and measuring the altitude and azimuth of the star on the CosmospHERE.
Sec. 71.

Sec. 74. To find the time of culminating, rising, and setting of the moon.

I. Mark the moon's place for the given day, according to astronomical tables, for twelve o'clock. Secs. 69 and 72.

II. Set the horizon, set the sky, set the clock, and bring the observer under the meridian. Sec. 40.

III. Turn the globe until the moon rise, culminate, or set, making allowance for her motion during the time marked by the clock, and turning the terrestrial globe so much more; then the hour will show its place at the required time.*

Remark. The orbit which the earth describes round the sun, or the moon round the earth, have been considered in this treatise as circles, while they possess the form of an ellipse; but this having been allowed for in the astronomical tables for the correct places, does not influence the accuracy of the above in solving problems.

* Besides the refraction of about thirty-five minutes in the horizon, the moon's parallax will frequently be much more: to find her true place will therefore require considerable corrections, particularly if in the horizon.

APPENDIX.

ON THE USE OF A COSMOSPHERE, OF AN ORBOGRAPH,
OF A LOXODROMOGRAPH, AND OF A SPHEROMETER :
INSTRUMENTS FOR CALCULATING

LATITUDE AND LONGITUDE AT SEA.

Sec. 75.—I. IT is not intended to give here a description of instruments commonly used at sea : that lead lines, log lines, compasses, gunter scales, charts, quadrants, sextants, octants, chronometers, and several other instruments, are useful and necessary for finding the place of a vessel at sea, is sufficiently well known. But the application of a Cosmospere for verifying calculations, for solving problems, and for showing whether corrections are additive or subtractive, appears equally useful and requisite in finding the place of a vessel at sea.

II. The most expert and best calculator is subjected to commit an error, or to write a cipher or a figure wrong, or to some or other mistake in solving problems, of which almost incredible examples might be cited ; but a Cosmospere, if once correctly constructed, and properly applied to corresponding objects, does not allow of such a mistake, as it is a representation, on a smaller scale, of every and the same object seen in the sky, and of every arc

measured or known, to find the required result, by placing similar parts corresponding to observations.

Sec. 76.—All problems of plane sailing, of parallel sailing, of middle latitude sailing, of oblique sailing, of globular sailing, of the time of tides at given places, and the setting and the velocity of currents, the effect of trade and variable winds, &c. may be better explained, and their influence, whether subtractive or additive, clearly shown and illustrated by a Cosmosphere.

Sec. 77.—The accuracy to be obtained by a Cosmosphere depends, first, on the accuracy and correctness of its fabrication or make. And supposing in this respect every thing requisite, or which may be desirable, be attained, the degree of accuracy to be got by a Cosmosphere depends, secondly, on the diameter of the instrument.

II. The diameter of a Cosmosphere gives the length of a degree, minute, &c.; and thus it is found (as it is supposed that an hundredth part of an inch can be distinctly observed), that a Cosmosphere 15 inches in diameter, or 47.13 inches, or 4713 hundred parts of an inch in circumference, will show five minutes, and a Cosmosphere 24 inches in diameter will show three minutes of an arc, or about 12 seconds of time, very distinctly without a magnifying glass.

III. But a Cosmosphere, considered as an instrument which has been made with all possible accuracy, always gives, in being applied for solving problems, the verification of any quantity found in terrestrial longitude or latitude, and in declination or right ascension of a celestial body, or the result of the solution of every problem, in two opposite places, which shows the degree of accuracy of the instrument.

IV. Besides, there may be applied a micrometer screw, with a magnifying glass to the tube of the axis of altitudes, and another one to the motion of the transparent

globe, and therefore smaller parts than the above-mentioned may be found by a Cosmosphere; and it results, consequently, that smaller parts than seconds of time may be found by a properly constructed and accurately made Cosmosphere: particularly so, as by repetition, or by repeated tracing of the corrected arguments, and repeated finding of the required part, a higher degree of accuracy is obtained in taking the arithmetical mean of all results, while the smaller parts are indicated by the micrometer screws.

V. This shows, however, at the same time, that a Cosmosphere which is not made with the degree of accuracy required, only leads to error and fallacy. No apparatus of the kind ought to be used, but such as has been thoroughly examined, and acknowledged as useful and correct by a board, or by an impartial individual, who feels the highest interest in the promotion of useful knowledge, and assisting the navigator in his perilous situation, after having been overtaken by a storm; or if he is out of calculation, and can only depend upon solutions derived from astronomical observations, such as measured altitudes, measured distances of heavenly bodies, or of two objects having been seen in a plumb-line during an observed time, &c, as will be afterwards shown.

VI. Some doubts might, however, arise respecting the degree of accuracy to be obtained by a Cosmosphere; but a spherometer,* or an instrument for representing and

* It is hardly requisite to give a description of this simply-constructed and most useful instrument. It consists of a divided ring, and two divided half rings. One of these semi-rings may be turned round its points 0 and 180 degrees, these lying in the same points of the ring, and the other semi-ring having the same division and motion; but being fixed to a ruler, it has besides the said motion another round its centre, in the plane of the divided surface of the instrument. The divisions on the ring, and both semi-rings, are to lie all in the surface of a globe. The inventor having used this instrument in the

solving problems of spherical triangles, if properly applied, will disperse these doubts *

VII. A spherometer may have two feet (more or less) in diameter; and if of these dimensions, it will show three minutes of an arc to an unaided eye very distinctly. By the verniers, and micrometer screws, and magnifying glasses, to be applied to it, and thrice repeated observations, however, three seconds of an arc, or two-tenths of a second in time, may be obtained by an expert observer.

VIII. A spherometer, giving and proving at the same time, if properly constructed, all solutions which may be found by solving problems of spherical triangles in the sky, and in general, is always to give a corresponding result with that found by a Cosmospere; it is therefore applicable and useful in examining the correctness and accuracy of a Cosmospere.

IX. A spherometer will always be a most useful instrument for verifying the solutions of problems in spherics, and consequently appears necessary for an astronomer and navigator in verifying the solutions found by calculation, if he be anxious to save time, instead of tediously repeating the operations necessary to verify the answers of a question.

X. A spherometer, although so useful in spherics, is however not adapted to show a loxodromic line; but for such purposes, a loxodromograph (an instrument so simply

presence of many, to verify calculations, has frequently had sufficient acknowledgments by competent judges of the great utility of a spherometer.

* This treatise is not adapted to the introduction of mathematical calculation. If the degree of accuracy is to be considered without instruments, the fluxions of spherical triangles are properly adapted for this purpose.—See the Author's work on Analytical Trigonometry, and the Fluxions of Plain and Spherical Triangles. Gottingen, 1806.

and in the German language.

constructed, that it requires no comment), has been applied to each of the semicircles. Its centre may mark any point of the division of the semicircles.

Sec. 78.—To trace a loxodromic line from a point on a terrestrial globe, or on a properly constructed map.

I. Point the small bar of the loxodromograph to the point of the compass under which the line is to be traced.

II. Apply the loxodromograph accordingly, putting it with the two hooks over the undivided ring (fixed to the horizon) of the terrestrial globe, so that the diameter through its point 0, and 180, will lie on the meridian, and the centre of the instrument over the given point of the globe, or of a map, to which it may be applied.

III. Trace a short line, having the length of a degree, or less, along the ruler from the centre of the instrument and from the given point.

IV. Continue this line, so that it may cut all the meridians under equal angles, by putting the loxodromograph, as already mentioned, with its centre to the end of the drawn line, until the required length be attained.

Remark.—All problems in navigation, where distances are to be traced under certain rhumbs, may be solved by this instrument on the globe, if the latitude and longitude of the place sailed from, the distance, and the course, are known.

Sec. 79.—I. Every observation at sea is to be corrected, as shown in astronomical works, and every year in an ephemeris, according to the depression or dip of the horizon, or the height of the observer's eye above the sea, and according to the refraction: both are always subtractive from an observed altitude, and consequently additive to a backwardly observed altitude.

II. But the sun, the moon, and the planet's places, are besides to be corrected according to the parallax of altitude and latitude, and to be reduced to their centre, if the

observations have been taken by the upper or lower, or eastern or western brim of the sun and moon. The parallax is always additive to an observed altitude.

III. The observation of a star is, however, to be corrected, besides the dip of the horizon, and the refraction, according to aberration and nutation. Precession is not mentioned here, because the place of a fixed star is always to be settled accordingly, and in regard to that of the sun, the moon, and the planets. Precession, aberration, and nutation are sometimes, according to the date, included in the longitude, latitude, declination, and right ascension of the stars; or their quantities may be found conformably in the tables. This being, however, sufficiently well known by the datas of an ephemeris, it is unnecessary to repeat things which may be found excellently laid down in many other works.

Sec. 80.—The pole being ninety degrees from the equator, and the zenith always at the same distance from the horizon, and the sum of the latitude and polar distance being always equal to ninety degrees (*Sec. 15*), as well as the sum of the altitude of a pole above the horizon and the polar distance of the zenith, gives the zenithal distance or the co-latitude always equal to the altitude of the equator above the horizon, which leads to finding the latitude of a place by observed altitudes. This is mentioned here, as a *Cosmosphere* will, in applying this to such an instrument, show and explain the mentioned facts clearly, and this should be kept in mind in solving all the following problems.

Sec. 81.—To find the latitude by a meridian altitude.*

* This is, of course, to be done according to the longitude of a place, reduced to time, reckoning twenty-four hours for the difference of 360° , or for a day, and making a proportionate allowance, according to the supposed longitude. The meridian altitude may be that of the sun, of the moon, or a star, &c.

I. Fix the bar of altitude, according to the observed and corrected altitude, (Sec. 79,) to the corresponding degree on the quadrant of altitude. Sec. 40.

II. Bring the ray of altitude over the declination of the celestial body, which is to be found in astronomical tables, or on an annalemma, or by the sun's place in the ecliptic, and is to be marked on the general meridian of the instrument; then the point in the axis of the tube of altitudes will show the latitude in degrees, minutes, &c.

Sec. 82.—To find the horary angle from an observed altitude of the sun, if the latitude of the place is known.

I. Correct the altitude to the true altitude, (Sec. 79,) and mark it by a bar of a ray of altitude on a quadrant of altitude, after bringing the tube of the axis of altitudes over the proper latitude on the general meridian.

II. Mark the proper place of the sun according to the day, the supposed longitude, and supposed hour, on the transparent globe, (Sec. 69, R. 2,) and bring the ray of altitude exactly over it. Then the horary angle will be shown by the distance on the equator between a meridian or an hour circle, (a large circle from one pole to the other, and through the ray of altitude,) and the divided side of the general meridian.

III. The horary angle may be before or after noon.

Sec. 83.—The horary angle found by an altitude of the sun, may be got likewise by a corrected altitude of the moon, or of a known star, &c., but the moon moving very fast, is seldom applied for this purpose.

Sec. 84.—The azimuth and amplitude of the sun, or of the moon, or of a star, are found as described in Sec. 82, 83, and 84, after setting the horizon. Then the divided side of the quadrant of altitude will show the azimuth and amplitude with its point 0 on the horizon.

Sec. 85.—To find the latitude and the horary angle from two observed altitudes of the sun, and the elapsed time between the observations.

I. Mark the sun's declination as given in the ephemeris, according to the supposed longitude, for the first observation on the transparent globe. Sec. 69, R. 2, and Sec. 71.

II. Mark the sun's declination as given in the ephemeris, according to the time elapsed, and supposed longitude, for the second observation on the transparent globe.

III. Set the rays of altitude over the points of the observed, but corrected altitudes (Sec. 79,) corresponding with the observation.

IV. Slide the tube of the axis of altitudes, and turn the transparent globe until the rays of altitude are exactly over the corresponding places of the sun.*

Then the point in the axis of altitudes will mark the latitude on the meridian, and the horary angle, or the time of the observations before noon and after noon, will be indicated at the same time by the angle comprised between the divided side of the general meridian, and the circle of the hour through the points marked by each ray of altitude before or after noon.

V. The azimuth and amplitude for both observations is found by setting the horizon, as described in Sec. 84.

Sec. 86.—These, as well as all the following problems, are proved to be true, by properly marking the observed and corrected, consequently true rays of altitudes on the quadrants of altitude of the instrument; as a circle of the same diameter, and laid through the points 0 of these quadrants, will be the horizon corresponding to the said quadrants of altitude, while the centre of the tube of the axis of altitudes shows the corresponding zenith.

Sec. 87.—The solution of the problems in Sec. 82 to 86 is, however, only true in case the observations have been made from one point: suppose, however, that the vessel has changed place, then of course the change in longi-

* If micrometer screws are applied, this may be done with great

tude as well as the change in latitude, whether towards or from the horizon of the first place of observation, is either subtractive or additive, in setting the rays of altitude on the proper point of the quadrants of altitude.

Sec. 88.—I. The finding of the latitude and the horary angle from two lunar observations, and the time elapsed between both, is done in a similar manner, after correcting the moon's altitude. Secs. 69, 71, and 85.

Sec. 89.—The same is the case with the finding of the latitude from two observed altitudes of a star, and the known difference of time between both observations.

Sec. 90.—Hence it results that, marking either the sun, or the moon, or a star, the altitude of which has been first observed, in the proper place of the transparent globe, and afterwards in the proper place of the sun, or the moon, or a star from the second observation, in making allowance for the time elapsed between both observations of the celestial objects, the latitude, the horary angle, and the azimuth, may be found with ease, dispatch, and a degree of accuracy hardly to be expected from a Cosmosphere, before a perfect knowledge of handling and using the instrument is obtained. The spherometer will always verify the found facit, if doubts should still be entertained respecting the accuracy.

Sec. 91.—To find the horary angle and azimuth by observing, in a known latitude, two stars in a plumb-line.

I. Bring the centre of the tube of the axis of altitudes over the given latitude on the general meridian, and mark the places of both stars (Secs. 69, 71, and 85,) on the transparent globe.

II. Turn the transparent globe until the properly corrected places of the two stars are exactly seen under the divided side of a quadrant of altitude. Then the arc on the equator, from the general meridian to the point of right ascension of each star, will show its horary angle, and the horizon, if properly set, the azimuth of both stars.

Sec. 92.—To find the latitude, if the horary angle of two stars is known, which are seen in a plumb-line.

I. Bring the stars' places, after marking them according to the horary angle, in a proper direction from the general meridian.

II. Set a quadrant of altitude to pass through them.

Then the point of the tube of the axis of altitudes will show the latitude of the place.

Sec. 93.—To find the latitude and the horary angle, by observing two known stars in a plumb-line, while another observes the same with two other stars.*

I. Mark and bring the places of the two pair of stars which have been observed in a plumb-line under the divided side of a quadrant of altitude. *Sec. 69, R. 2.*

II. Slide the tube of the axis of altitudes along the meridian, and turn the transparent globe until each pair of the observed stars lie under the divided side of each of the quadrants of altitude.

Then the point in the centre of the tube of the axis of altitudes will mark the latitude, and the horary angle will be indicated on the equator. *Sec. 82.*

III. The azimuth is found by setting the horizon according to the found latitude. *Sec. 84.*

Sec. 94.—Should two stars have been observed in a plumb-line sometime before two other stars were seen in a plumb-line, then the interval of time is to be taken into calculation, as described in *Sec. 87.*

Sec. 95.—It is generally known that longitude is found by the difference of time, or by the horary angle and the observed time of an adjusted chronometer, at the moment when the observation for finding the horary angle was made.

Therefore it results, that longitude may be calculated by two observed altitudes.

Sec. 96.—To find the latitude, the longitude, and azimuth

* This is a supposition which will not happen very often, except
rs of the 5th or 6th magnitude.

from two observed altitudes of two stars with the assistance of a chronometer.

I. Mark the places of these two stars with accuracy on the surface of the transparent globe. Sec. 69, R. 2.

II. Mark the observed and corrected altitudes by the rays of altitude on the quadrants of altitude, and bring the marked rays of altitude on the quadrants over the corresponding places of the stars, as exact as possible, by sliding the tube of the axis of altitudes on the meridian, and turning the transparent globe.

Then the point in the centre of the tube of the axis of altitudes will show the latitude, while the quadrants mark on the horizon (if properly set) the azimuth.

III. Mark the degrees, minutes, &c. of right ascension on the equator of the transparent globe which lie exactly under the division of the general meridian.

IV. Find the right ascension of the zenith of the place, with which the chronometer corresponds, and according to the hour indicated by it. Sec. 69, R. 2.

V. Take the difference, or the sum of the right ascension of the zenith of the place of the observer, found in III, and of the place with which the chronometer corresponds, IV, to find the real difference of right ascension.

This will be equal to the required longitude.

Sec. 97.—It need only be mentioned here, that the same problem can be solved after observing, at the same time, two pair of known stars, each pair in a vertical line. A solution of such a problem would only be a repetition of Sec. 69, Sec. 93, and Sec. 96.

Sec. 98.—I. The time of a place of an observer comparatively to that of a place from which longitude is to be calculated is, as is generally known, best ascertained by lunar distances, or occultations of stars. The observed altitudes differ, however, from the true altitudes; and a shorter or greater distance of two objects from the horizon causes

always a material difference in the distance of such objects from each other, this being always measured by a large circle.

II. It hence results clearly, if the distance of the moon, and the sun, or a star have been measured, that they will never coincide with the real or true distance, as the correction of the apparent altitudes are subjected to different corrections; and this proves clearly the great utility and necessity of measuring the altitudes of the sun and stars, together with that of the moon, if a lunar distance from either is to be found with accuracy.

III. To simplify such calculations, a profusion of admirably constructed tables have been introduced by the ingenuity of the human mind; but in many instances their extent has frequently defeated their object, and surrounded the subject with a kind of technical cloud, which more skilful calculators properly try to avoid, and which becomes forbidding to such as are less expert in solving problems, by formulas, of which they cannot prove the mathematical truth.

IV. The ephemeris for a certain place gives, for every three hours, the true distance of the moon from the sun, or a star; and from this, the true place of the moon before and after the observed distance can be traced on the surface of the transparent globe; and if these two places are united by a line, this will show a part of the moon's orbit in the sky. Sec. 69, R. 2.

V. The moon changes her position in her orbit every day about 13 degrees, or her mean diurnal motion in her orbit is about 13 degrees; it amounts, however, sometimes, from about 11.5 to 15.5 degrees of right ascension, and from about 1.5 to 3.5 degrees in declination; it therefore results, that her mean motion in her orbit during every minute of time (the 1440th part of a day) is little more than half a minute of an arc. Should, therefore, an observed and corrected lunar distance have a fault of about half a minute

of an arc, this would give rise to a mistake of about a minute in time, or about 15 minutes of an arc, or about 15 miles in longitude. Hence may be perceived what accuracy is required in taking lunar distances, and that a single observation cannot give a result, the accuracy of which may be much depended upon.

VI. The corrected altitudes having so much influence upon the accuracy of the distance of the moon from the sun, or a star, it is clearly seen that they ought to be taken as correctly as possible, if accuracy be expected.

VII. If the observations necessary for a lunar distance are required, it will be best to make them as follows:—1, the altitude of the sun or star; 2, the altitude of the moon; 3, a lunar distance; 4, the altitude of the moon; 5, the altitude of the sun, or a star, noticing always the exact time of each observation, to get the arithmetical mean of the time, and of the observed altitudes and distances. Such a set of observations is, however, not sufficient to be depended upon, and at least three such sets of observations are to be made, and the arithmetical mean of them may only be considered as tolerably good arguments for the true places and distances of the sun, or a star, from the moon.

VIII. The horary angle, or the time of the vessel, is always requisite to be known, in taking a lunar distance, to find the time of another place; and great care is to be taken to have the time-piece applied for this purpose properly adjusted.

IX. Should the vessel have changed its position during the time that such observations have been taken, a proper allowance is to be made for this change of place. It will, however, always cause more corrections of the observed altitudes, and more difficulty; and this appears a sufficient reason to stop the course of a vessel during the time that such observations are made.

X. The true altitude of a star, or the sun and the moon, will likewise give the true azimuth, as different altitudes of either of them will give, in the same latitude, a different azimuth and amplitude; and this again shows, that great accuracy is required in taking altitudes for finding the deviation of the compass.

Sec. 99.—To find the time of a place for which an ephemeris gives the moon's distance from the sun or a star, if the latitude and the time of the vessel are known.

I. Mark the correct place of the star, for the given hour, on the surface of the transparent globe, (Sec. 69,) and fix a bar on of a ray of altitude, in the observed and corrected altitude, on a quadrant of altitude, as exact as possible.

II. Trace the two places of the moon according to the ephemeris, one for the next greater, and the other for the next smaller distance, as the observed one between the moon and the sun or star on the surface of the transparent globe, and unite the two traced places of the moon by a line, to show a part of her orbit. *Sec. 98, IV.*

III. Divide this line into proper parts to show the difference of time in sufficiently small parts, from the time given in the ephemeris of both marked places of the moon.

IV. Mark by a bar of a ray of altitude the moon's corrected altitude, on the other corresponding quadrant of altitude, with accuracy.

V. Bring the centre of the tube of the axis of altitudes into the proper latitude, and the representation of the ray of the corrected altitude of the sun or star, over the corresponding marked place on the surface of the transparent globe; then the angle of the hour of the observed object is to correspond with the hour of the vessel, if no fault has been committed.

VI. If no fault is observed, then fix the transparent ball in this position.

Bring the representation of the corrected ray of the

moon's altitude over the place where it intersects the line drawn between the two marked positions of the moon.

Then the time of the place for which the ephemeris has been calculated, will be shown on the divided line between the two marked places of the moon on the surface of the globe.

Sec. 100.—I. From the known apparent time of a place for which the ephemeris has been calculated, at the moment of the observation, and the known angle of the hour, or the time of the vessel for the same moment, longitude may be calculated without further comment. *Sec. 98.*

II. It remains only to mention what time for observing the moon's distance, and the altitudes of the sun, or a star, and the moon, will be subject to the least fault.

III. It is generally known and shown by the Cosmospere, with the quadrants of altitude, and in turning the transparent globe, that, first, the altitudes of celestial bodies vary the most in the same interval of time when they are about 90 degrees from the meridian; 2ndly, that, however, altitudes smaller than 20 degrees are subject to considerable mistakes; and, 3dly, that a circle round the axis of altitudes, described by a certain altitude, marked on a quadrant of altitude in turning it, or the alrancantarath of the given altitude of the moon, intersects the moon's orbit more perpendicularly for the northern hemisphere while her declination decreases, if her place is in the eastern part of the sky; and when the moon's declination increases, the same will take place in the western hemisphere.

IV. Adapting this to the southern hemisphere, the same as to the northern, and considering both cases, it results,

First, That the distance of the moon from the sun, or a star, to be taken, ought never to exceed 90 degrees, while the altitudes to be measured are to be above 23 degrees;

2ndly, That the distances of the moon, for her northern hemisphere, while her declination decreases, are to be taken

from celestial bodies to the west of the moon; but when the declination increases from celestial bodies, to the east of her; and the contrary for the southern hemisphere.

Sec. 102. A perpendicular line through the moon's centre, and a star, if measured at the same time, while its distance is taken, will always contribute to accuracy, and ought never to be neglected. When the moon's almucantarath intersects her orbit on the instrument, the corrected place of the said star is to lie under the divided side of the quadrant.

Sec. 103.—The spherometer serves likewise to prove the accuracy of this problem in marking the two observed altitudes on the semicircles, taking the division on the circle as that of the azimuth. One of the loose quadrants will then show the corrected distance. And by the excess of the corrected distance over the given distance in the ephemeris, the hour is found by the fourth proportional to the excess, and the ratio of the time between the distances (given in the tables), to these distances.

Sec. 104.—I. In the same manner as lunar distances serve for finding the time at a place for which an ephemeris has been calculated, may likewise be found by observed occultations of stars, if the time of the vessel is observed when the brim of the moon comes in a vertical line with a star which lies in, or not above ten minutes from the moon's orbit.

II. The observations are to be made in the same way as described in *Sec. 98*, and the operations are similar to those mentioned in *Sec. 99*; and as it is only required to set the sky properly, and after marking a part of the moon's orbit, to find the corrected place of the moon at the observed time of the vessel by an almucantarath, it is unnecessary to repeat what has been shown there.

THE END.

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